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SPECIALIZED VARIETIES OF PUCCINIA GLUMARUM, AND HOSTS FOR VARIETY TRITICI[1]

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INTRODUCTION

Since the discovery of stripe rust in the United States, in 1915, a systematic study of the disease has been conducted by the Office of Cereal Investigations of the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Oregon Agricultural Experiment Station, and, later, with the Idaho Agricultural Experiment Station. This paper is the third of a series of contributions to our knowledge of stripe rust in the United States. Former papers (*2*, *10*)[3] have dealt with the economic importance and geographical distribution of the disease and with the life history, taxonomy, and morphology of the causative organism. This paper will deal with the known hosts of the rust, our present knowledge of its specialized varieties, and with the comparative susceptibility of certain wheat varieties to *Puccinia glumarum tritici* Erikss. & Henn., as indicated by field and greenhouse experiments.

HOSTS

Eriksson (*4*), in his original report upon *Puccinia glumarum*, when it was separated from the now obsolete *Puccinia rubigo-vera* (DC.) Wint., named wheat, barley, rye, *Elymus arenarius*, and *Agropyron repens* as hosts for the new form. Saccardo (*16*, *p. 380*) lists the following hosts: *Brachypodium silvaticum*, *Bromus mollis*, *Calamagrostis epigeios*, *Hordeum vulgare*, *Secale cereale*, *Triticum caninum*, *T. compactum*, *T. dicoccum*, *T. desertorum*, *T. distichon*, *T. durum*, *T. giganteum*, *T. polonicum*, *T. repens*. Hecke (*7*) reports the unpublished work of K. Barfus in which he lists *Dactylis glomerata* as an additional host.

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[3] Reference is made by number (italic) to "Literature cited," p. 400-401.

Stripe rust has been found in the western part of the United States on wheat, barley, rye, spelt, and emmer in the field, and upon 33 wild grasses. The wild grass hosts found naturally infected include seven species of *Agropyron: A. spicatum* (Pursh) Scribn. & Smith, *A. cristatum* (L.) Gaertn., *A. dasystachyum* (Hook.) Scribn., *A. intermedium* (Host) Beauv., *A. violaceum* (Hornem.) Lange, *A. lanceolatum* Scribn. & Smith; eight species of Bromus: *B. marginatus* Nees, *B. pacificus* Shear, *B. sitchensis* Trin., *B. carinatus* Hook. & Arn., *B. carinatus hookerianus* (Thurb.) Shear, *B. rubens* L., *B. brizaeformis* Fisch. & Mey., and *B. polyanthus* Scribn.; six species of Elymus: *E. canadensis* L., *E. condensatus* Presl, *E. glaucus* Buckl., *E. macounii* Vasey, *E. striatus* Willd., and *E. virginicus* L.; six species of Hordeum: *H. jubatum* L., *H. gussoneanum* Parl., *H. murinum* L., *H. nodosum* L., *H. pusillum* Nutt., and *H. caespitosum* Scribn.; two species of Hystrix: *H. patula* Moench., and *H. californica* (Boland.) Kuntze; three species of Sitanion: *S. jubatum* J. G. Smith, *S. hystrix* (Nutt.) J. G. Smith, and *S. longifolium* J. G. Smith; one species of Phalaris, *P. paradoxa* L., and one wild species of Triticum, *T. aegilops* Beauv.

The rust has been found on wheat in nearly all the western States, but has been reported on barley from only four districts, viz: Eastern Washington, eastern Oregon, western South Dakota, and central California. Only three collections have been made on rye, these being from northern Idaho, eastern Oregon, and western Oregon. The possible significance of the limited distribution of the rust on the last-named hosts will be discussed later.

The occurrence of stripe rust on *Bromus marginatus*, *Elymus canadensis*, *E. glaucus*, *Hordeum nodosum* and *H. jubatum* has been found to be quite general within the known geographic limits of the various grasses and of the parasite. *Hordeum murinum* was very generally infected in 1917 and in 1922 in the lower coast district of California, but has never been found so infected in other sections of the Pacific Coast where this host commonly occurs and where the rust has been present on other grasses. The collections on other hosts have been few in number and indicate that they are not as common hosts for the disease as the others already mentioned. In some cases, at least, they are more limited in their distribution.

As will be shown in a forthcoming paper of this series of studies,[4] a number of collections of stripe rust had been made prior to May, 1915, when stripe rust was first recognized in the United States. These had been identified as several other rusts. Among these collections appear two hosts which have not been found naturally infected since that time. They are *Bromus carinatus hookerianus* (Thurb.) Shear, and *Sitanion longifolium* J. G. Smith.

The variety peculiar to wheat, *Puccinia glumarum tritici* Erikss. and Henn., has been found capable of infecting the following additional hosts when inoculations were made in the greenhouse: *Agropyron tenerum* Vas. and *A. smithii* Rydb.; *Bromus hordeaceus* L., *B. inermis* Leyss., *B. commutatus* Schrad., *B. sterilis* L., *B. tectorum* L., *B. rigidus* Roth, and *B. ciliatus* L.; *Elymus australis* Scribn. and Ball, and *E. robustus* Scribn. and Smith. A detailed discussion of the methods used and the results obtained in connection with the above determinations will be given later under the discussion of specialized races of *P. glumarum*.

[4] In manuscript.

Since the completion of the foregoing studies, headquarters for the investigations on stripe rust have been transferred from Corvallis, Oreg., to Moscow, Idaho, and the research is now being carried on by the senior author and Mr. J. M. Raeder. Since the transfer, the following additional hosts for *Puccinia glumarum tritici* have been determined by greenhouse inoculation: *Agropyron tenerum longifolium* Scribn. and Smith., *A. caninum* (DC.) Roem. and Schult., *Bromus purgans latiglumis* (Scribn.) Shear, *B. lanuginosus* Poir., *B. erectus* Huds., *B. macrostachys* Desf., *B. rigidus* Roth, *B. frondosus* (Shear) Woot. and Standl., *B. richardsonii* Link, *B. adoensis* Hochst., *Hordeum maritimum* Roth, *H. bulbosum* L., *Phalaris canariensis* L., and *Silanion hystrix* (Nutt.) J. G. S. The grasses in this list, with those listed previously, comprise fifty-nine species of common wild grasses which are known to be hosts for stripe rust as it occurs in the United States. Thirty-three of these have been found naturally infected, and twenty-six of them determined by artificial inoculation with *P. glumarum tritici*. Doubtless other hosts will be added to this list as our knowledge of this rust becomes more complete.

SPECIALIZED VARIETIES

Eriksson (*4*) named five specialized varieties of *Puccinia glumarum*, based on inoculation experiments carried on by him. These were *P. glumarum tritici* on wheat, *P. glumarum hordei* on barley, *P. glumarum secale* on rye, *P. glumarum elymi* on *Elymus arenarius* and *P. glumarum agropyri* on *A. repens*. He states that the varieties on wheat and barley appear to be sharply fixed (scharf fixiert); that is, he could not secure infection upon barley or rye with the variety *tritici*, or upon wheat or rye with the variety *hordei*. The variety *secale* appeared to be less sharply fixed, since he secured slight infection upon wheat inoculated with this variety. He considered that he might have had a mixed culture in the latter case. Neither of the varieties on *Agropyron repens* and on *Elymus arenarius* would infect wheat, barley, or rye, nor was he able in either case to reinfect the original host.

It appears then that Eriksson had good evidence for establishing the varieties *P. glumarum tritici* and *P. glumarum hordei*, but there is some question as to the evidence in the case of the other three varieties.

In the field survey for stripe rust, conducted by the writers, an attempt has been made to record not only the name and location of infected hosts but also the name of other near-by grasses and cereals. It was thought that these notes might furnish valuable data regarding the spread of the rust from host to host in the field and also supplement the study on specialized varieties being conducted in the greenhouse.

As stated above, *Hordeum jubatum* and *Bromus marginatus* are two of the most common hosts for *P. glumarum* in the northwestern States. Wherever these two grasses have been found growing near each other, if one was infected, the other usually was infected also. With few exceptions, wherever infection was common on either of these two wild hosts, stripe rust could be found also on wheat if plants of a susceptible variety could be found growing near by. This also was true to a more limited extent of *Elymus glaucus*, *Hordeum nodosum*, *Elymus canadensis*, and *Elymus condensatus*, although these latter grasses are much more limited in their distribution and do not appear to be as common hosts for stripe rust as are the two first named.

In 1917, and again in 1922, *Hordeum murinum* was found to be one of the most common hosts for stripe rust along the Pacific Coast in southern California. Very seldom was any other host found infected, although other possible hosts often were growing in close proximity.

EXPERIMENTAL METHODS

The greenhouse experiments in the study of specialized varieties of *Puccinia glumarum*, as well as in the testing of wheat varieties for susceptibility to stripe rust, were carried on at Corvallis in a small wing of the greenhouse of the Oregon Agricultural Experiment Station. The methods used in greenhouse inoculations were, with certain modifications, like those employed by Stakman and Piemeisel (*18*) in their stem-rust studies. Every precaution was taken to guard against chance infections.

Seedlings were used with few exceptions, and were inoculated on the first or primary leaf. Plate 1, A and B, shows the method of preparing the seedlings for inoculation and the devices used for obtaining favorable conditions for infection. In every case the plants in a given pot were divided into two groups before any inoculations were made. This was done usually by pulling up or cutting close to the soil those in a line through the center of the pot. A piece of string was then laid on the soil between the two groups of seedlings. One half of these were inoculated and the other half left as control plants. In only one or two instances did any infection develop on the controls, and then only on a plant immediately adjacent to the inoculated ones. In such cases the results were not considered.

Inoculations were made by carefully transferring fresh urediniospores to the upper side of the leaf by means of a small scalpel. Melchers (*11*) found that he could obtain satisfactory infection on wheat with *Puccinia graminis tritici* E. & H. by inoculating the under side of the leaf. This did not prove to be the case with *Puccinia glumarum tritici*. Several trials were made by taking wheat plants of the same age and variety and inoculating part on one side of the leaf and part on the other. Only a very few infections resulted from the inoculations made on the under side, while nearly 100 per cent of those inoculated on the upper side of the leaf became infected.

At first, bell jars and battery jars were used for incubation chambers. Later, however, shallow tubs covered with a window sash were used to good advantage. After inoculation, the pots were placed in a tub containing about 2 inches of water, covered, and left in this moist chamber for 48 hours. They then were removed to the greenhouse bench. The various strains of the rust were kept in separate compartments in the greenhouse, and were isolated by means of partitions made of fine cheesecloth.

RESULTS

Inadequate greenhouse space made it impossible to work with a large number of collections of stripe rust. All of those studied proved to be *Puccinia glumarum tritici*. Each infected wheat readily, rye slightly, barley very slightly, if at all, and oats not at all. Table I shows the results of inoculations made on various varieties of barley and rye with urediniospores from wheat. As barley has been found heavily infected in the field several times, it appears that there must be a distinct specia-

rel race which infects that host. Thus far, it has not been possible to ain the race for experiment from barley.

Under "Character of Infection" the following five grades of infection ve been used:

0—No uredinia; flecks and dead areas sometimes present; portions of leaves sometimes killed or discolored (Pl. 3 and 4).

1—Uredinia few or minute, generally surrounded by dead areas; portions of leaves sometimes killed or discolored (Pl. 5).

2—Uredinia normal in appearance, but few and scattered; discoloration of leaf tissues common (Pl. 6, A).

3—Uredinia normal, moderately abundant; little discoloration of leaf tissue (Pl. 6, B).

4—Uredinia normal and very abundant, appearing uniformly over surface of inoculated leaf; no discoloration in early stages of infection (Pl. 6, C).

"Br.," in Table II, indicates that there was pronounced browning of the tissue around the border of the dead areas produced by the rust (See Pl. 3, A).

TABLE I.—*Results obtained when barley and rye varieties were inoculated with uredinio-spores of stripe rust from wheat*

Crop and variety.	Number of plants.		Character of infection.
	Inoculated.	Infected.	
BARLEY:			
Sandrel	49	0	0
O. A. C. Sel. No. 7	45	0	0
O. A. C. Sel. No. 8	36	0	0
Black Hull-less	48	1	2
Tennessee Winter	33	0	0
White Hull-less	63	0	0
Peruvian	48	0	0
Hannchen	34	2	2
Trebi	68	10	2
RYE:			
Abruzzi	43	6	3
Common	43	12	3

The results of various inoculations made with *Puccinia glumarum tritici* from several sources on various wild grasses and cereals to ascertain which were hosts for the rust are presented briefly in Table II. In some cases the results represent only one trial, while in other instances several experiments were made. Chul wheat was used in all cases.

TABLE II.—*Results of inoculation of urediniospores of Puccinia glumarum tritici from different original and immediate hosts on numerous wild grasses and cereal*

Original host.	Immediate host.	Plant inoculated.	Number of experiments.		Number of plants.		
			Infection obtained.	No infection obtained.	Inoculated.	Infected.	
Wheat	Wheat	*Agropyron cristatum*	1		4	3	
Do	do	*Agropyron desertorum*	1		30	28	
Do	do	*Agropyron intermedium*	1		18	12	
Do	do	*Agropyron smithii*	1	2	45	5	
Do	do	*Agropyron spicatum*	1		2	2	
Do	do	*Agropyron tenerum*	1	1	39	12	
Do	do	*Bromus hordeaceus*	1		25	2	
Do	do	*Bromus inermis*	1	2	74	2	
Do	do	*Bromus marginatus*	2		42	35	
Do	do	*Bromus polyanthus*	2		20	15	
Do	do	*Bromus secalinus*		2	24	0	
Do	do	*Dactylis glomerata*		4	50	0	
Do	do	*Elymus canadensis*	1		14	14	
Do	do	*Elymus glaucus*	1		16	12	
Do	do	*Elymus condensatus*	2		28	20	
Do	do	*Elymus virginicus*	1		30	28	
Do	do	*Hordeum gussoneanum*	1		12	7	
Do	do	*Hordeum jubatum*	3		50	35	
Do	do	*Hordeum nodosum*	2		35	20	
Do	do	*Hordeum pusillum*	1		13	13	
Do	do	*Hystrix hystrix*	1		13	13	
Do	do	*Sitanion jubatum*	1		8	7	
Do	do	Barley	2	12	235	13	
Do	do	Oats		4	50	0	
Do	do	Rye	3	5	120	20	
Do	*Bromus marginatus.*	Wheat	3		50	40	
Do	*Elymus canadensis.*	do	1		9	9	
Do	*Elymus glaucus.*	do	1		9	5	
Do	*Sitanion jubatum.*	do	1		9	8	
Bromus marginatus.	Wheat	*Agropyron smithii*		1	3	0	
Do	do	*Arrhenatherum elatius.*		1	22	0	
Do	do	*Beckmannia erucaeformis.*		1	10	0	
Do	do	*Bromus carinatus*	1	1	26	1	
Do	do	*Bromus ciliatus*	1	1	14	2	
Do	do	*Bromus hordeaceus*	1	1	40	2	
Do	do	*Bromus inermis*	1	1	29	4	
Do	do	*Bromus japonicus*		2	25	0	
Do	do	*Bromus pratensis*		1	30	2	
Do	do	*Bromus secalinus*		1	10	0	
Do	do	*Bromus tectorum*		1	25	0	
Do	do	*Elymus australis*	1		20	2	
Do	do	*Elymus canadensis*	1		14	5	
Do	do	*Elymus glaucus*	1		10	3	
Do	do	*Festuca elatior*		1	20	0	
Do	do	Barley		2	13	0	
Do	do	Wheat	7		140	114	

TABLE II.—*Results of inoculation of urediniospores of Puccinia glumarum tritici from different original and immediate hosts on numerous wild grasses and cereals*—Cont'd.

Original host.	Immediate host.	Plant inoculated.	Number of experiments.		Number of plants.		Character of infection.
			Infection obtained.	No infection obtained.	Inoculated.	Infected.	
Bromus marginatus.	*Bromus marginatus.*	*Bromus marginatus.*	1	.....	10	8	4
Do	do	*Bromus sterilis*	1	.....	8	8	4
Elymus glaucus.	Wheat	*Agropyron caninum.*	.....	1	12	0	0
Do	do	*Agropyron repens*	.....	1	10	0	0
Do	do	*Agropyron smithii*	.....	1	13	0	0
Do	do	*Agropyron tenerum*	.....	2	20	0	0 Br.
Do	do	do	.....	1	5	0	0
Do	do	*Beckmannia erucaeformis.*	.....	1	11	0	0
Do	do	*Bromus carinatus*	.....	1	30	0	0 Br.
Do	do	*Bromus ciliatus*	.....	1	13	0	0 Br.
Do	do	*Bromus inermis*	.....	2	30	0	0 Br.
Do	do	*Bromus marginatus*	3	.....	42	36	4
Do	do	*Bromus polyanthus*	1	.....	8	4	4
Do	do	*Bromus pratensis*	.....	1	14	0	0 Br.
Do	do	*Bromus secalinus*	.....	2	28	0	0
Do	do	do	.....	1	10	0	0
Do	do	*Bromus sterilis*	1	.....	7	7	3
Do	do	*Bromus vulgaris*	.....	1	12	0	0 Br.
Do	do	*Elymus condensatus*	1	.....	13	10	4
Do	do	do	1	.....	8	4	3
Do	do	do	1	.....	28	14	3
Do	do	*Elymus glaucus*	5	.....	120	100	4
Do	do	*Elymus robustus*	1	.....	4	1	4
Do	do	*Elymus striatus*	.....	1	8	0	0
Do	do	*Festuca elatior*	.....	1	15	0	0
Do	do	*Festuca pratensis*	.....	1	10	0	0
Do	do	*Hordeum gussoneanum.*	1	.....	10	6	3
Do	do	*Hordeum murinum*	2	1	32	10	1
Do	do	do	2	2	62	8	2
Do	do	*Hordeum nodosum*	2	.....	20	18	4
Do	do	*Sitanion jubatum*	2	.....	15	14	4
Do	do	Barley	.....	4	32	0	0
Do	do	do	.....	1	20	0	0
Do	do	Emmer (Black Winter).	2	.....	35	30	4
Do	do	Oats	.....	1	15	0	0
Do	do	Rye	.....	1	15	0	0
Do	do	Wheat	5	.....	125	110	4
Hordeum jubatum.	do	*Agropyron repens*	.....	1	9	0	0
Do	do	*Bromus japonicus*	.....	1	6	0	0 Br.
Do	do	*Bromus polyanthus*	1	.....	19	19	4
Do	do	*Bromus sterilis*	1	.....	6	3	1
Do	do	*Bromus tectorum*	1	1	23	3	1
Do	do	*Bromus rigidus*	1	.....	10	2	1 Br.
Do	do	*Elymus glaucus*	1	.....	12	5	4
Do	do	*Hordeum murinum*	1	2	20	3	1
Do	do	*Lolium temulentum*	.....	1	13	0	0 Br.
Hordeum nodosum.	do	*Bromus polyanthus*	2	.....	22	19	4

TABLE II.—*Results of inoculation of uredinio spores of Puccinia glumarum tritici from different original and immediate hosts on numerous wild grasses and cereals*—Cont'd.

Original host.	Immediate host.	Plant inoculated.	Number of experiments.		Number of plants.		Cha...
			Infection obtained.	No infection obtained.	Inoculated.	Infected.	
Hordeum nodosum.	Wheat.....	*Sitanion jubatum*...	2	.....	26	24	4
Do.....	do.....	Rye.....	.....	1	18	0	0
Do.....	do.....	Wheat.....	2	.....	42	30	4
Do.....	*Bromus polyanthus.*	*B. carinatus*.....	.....	2	46	0	2 to
Do.....	*Hordeum nodosum.*	*Elymus condensatus.*	1	.....	12	8	3
Do.....	do.....	*Bromus commutatus*.	.....	1	20	0	0
Do.....	do.....	*Hordeum nodosum*..	1	.....	12	12	4
Do.....	do.....	*Dactylis glomerata*...	.....	5	60	0	0

The list in Table II includes 48 species of wild grasses which have been shown to be hosts of *P. glumarum tritici*. It includes 19 species of Bromus, 11 species of Agropyron, 7 species of Elymus, and 1 species each of Hystrix, Sitanion, and Phalaris. Collections have been made in the field on 12 additional infected grass hosts, but it has not been possible to determine if they were infected with the race which goes to wheat. These 12 species include: *Agropyron inerme* (Scribn. and Sm.) Rydb., *A. dasystachyum* (Hook.) Scribn., *A. caninum*, *Bromus pacificus* Shear, *Bromus sitchensis* Trin., *Bromus carinatus hookerianus* (Thurb.) Shear, *Bromus brizaeformis* Fisch. and Mey., *Hordeum caespitosum* Scribn., *Hystrix californica* (Boland.) Kuntze, *Elymus striatus* Willd., *Elymus macounii* Vasey, *E. triticoides* Buckl., *Phalaris paradoxa* L., *Sitanion hystrix* (Nutt.) J. G. Smith, *Sitanion longifolium* J. G. Smith, and *Agropyron cylindrica* Beauv.

Only one specialized variety apparently has been used in these inoculation experiments, and this appears to be *Puccinia glumarum tritici* Eriks. & Henn. There are some indications that at least one other variety is present in the United States. This probably is *Puccinia glumarum hordei* Eriks. & Henn., as indicated by the fact that barley has been found heavily infected in a few instances, while the race commonly found on wheat does not pass readily to barley. There also is evidence that the rust on *Hordeum murinum* may not be the variety commonly found on wheat. A discussion of these varieties is reserved for a later paper.

In only one case in Table II does there occur a difference of more than two in the grade of infection recorded when the same host was inoculated with the rust taken from the different hosts. When *Bromus sterilis* was inoculated with rust spores from *Hordeum jubatum* the infection was recorded as 1. When spores were taken from *Bromus marginatus* and from *Elymus glaucus* the result was a grade of 4 in each case. There are two possible explanations for these results. There may have been two strains of *Puccinia glumarum tritici* involved, or it is possible that there were two strains of *Bromus sterilis* used, as the seed came from

two different sources. During the course of this work there have been several indications that there may be strains of the specialized variety *Puccinia glumarum tritici*, the same as exist in *P. graminis tritici*, as shown by Stakman and Piemeisel (*18*). During the course of these studies evidence has accumulated indicating the possible existence of varieties or strains of various grasses which may react very differently to a given strain of the parasite. This phase of the question is under investigation.

SUSCEPTIBILITY OF WHEAT VARIETIES TO PUCCINIA GLUMARUM TRITICI

No attempt will be made here to review the very extensive literature upon the subject of rust resistance. Complete reviews of the subject from various angles have been made by Eriksson and Henning (*5*), Biffen (*1, p. 40-44*), Comes (*3*), Nilsson-Ehle (*14*), and, more recently, Henning (*8*). The study in Europe on the relative resistance of various wheats to *Puccinia glumarum* also has been extensive. As might have been foreseen, the results obtained have varied greatly, for the men engaged have worked under entirely different conditions, and undoubtedly with different strains of the varieties of wheat used as well as with different strains of the rust.

This paper summarizes the results obtained through study of a large number of varieties of wheat for resistance to *Puccinia glumarum tritici* as it occurs in western Oregon. The wheat varieties were obtained partly from the Office of Cereal Investigations and partly from the Department of Farm Crops of the Oregon Agricultural College. Every precaution has been taken to keep these varieties free from mixtures.

Both greenhouse and nursery studies were carried on at Corvallis, Oreg. In all, 337 varieties and strains of wheat were grown in the rust nursery. Only 163 of these are included in Table III. The remainder were grown in only one year and therefore are not included. Ninety-two varieties were studied under greenhouse conditions. Not all of the 163 varieties were sown in the nursery in each of the three seasons through which the experiments were extended. In 1918 only 72 varieties and strains were grown. In 1919 additional seed was obtained and 142 varieties and strains were grown. Still other varieties were added in 1920. Likewise, not all of the 92 varieties were grown in the greenhouse in any one season. Because of inadequate space and assistance it was impossible to study in the greenhouse all of the varieties that were used in the rust nursery.

NURSERY EXPERIMENTS

In the rust nursery the varieties were all sown in rod rows. In some cases replicated sowings were made; in other cases there was only one row of each variety. All varieties of which seed was available were sown in the fall regardless of whether they were of winter or spring habit. Under the climatic conditions prevailing at Corvallis it was found that spring varieties, when sown in the autumn, survived the winter in practically as good condition as the winter varieties. In the first two years such varieties as were known to be of spring habit and of which seed was available were sown in duplicate rows in the spring. In 1920 all varieties of which seed was available were sown again in duplicate rows in the

spring regardless of whether they were winter or spring wheats. Of course the winter varieties did not head when sown in the spring nursery, so that it was impossible to get notes on head infection.

The methods of making inoculations in order to induce an epiphytotic of stripe rust in the nursery were such as seemed to offer the best conditions possible for an abundant and widespread infection. Border rows of Chul, one of the most susceptible varieties of wheat, were sown around all of the plots. These border rows were inoculated both by spraying a suspension of urediniospores over their entire length and by hand inoculation of individual plants at intervals in them.

In addition to the border-row inoculations, one end of each varietal row was sprayed with a spore decoction and individual plants in every row were hand inoculated. Hand inoculations were made by smearing spores on the leaves with a scalpel, spraying the plants with water, and covering the inoculated plants with inverted flower pots for a period of 48 hours. The quantity of infection on the border row served as a control, showing whether or not climatic and other conditions were favorable for abundant infection.

The results of the 3-year study of the effects of such inoculations on 163 varieties of common, club, poulard, durum, and Polish wheats, and emmer, spelt, and einkorn, when grown in the nursery, are shown in Tables III and IV.

The method used to indicate the quantity of infection recorded in Table IV needs a word of explanation. It seemed to the writers that the usual method of estimating the quantity of rust on cereals was not the best for accurately indicating the quantity of stripe rust present. It was found that varieties differed widely in the proportion of the plants in the row which showed infection, as well as in the quantity of rust on those plants which were rusted. In other words, there was much variation in the rapidity and extent of the spread of the rust on the different varieties.

Table III shows, for each variety, the proportion of the plants which were rusted at the Oregon Agricultural Experiment Station in the fall of 1917 and the spring of 1918, expressed in percentages, and the degree of rustiness of these infected plants, expressed in terms of a scale ranging from 1 to 10. The degree of infection refers to the proportion of plant surface covered with rust. This necessitates the recording of two numbers to indicate the comparative susceptibility of each variety. In order to reduce these figures to a single product which would express at a glance this comparative susceptibility, the following plan was devised. The product of the percentage of plants infected by the degree of infection would give in comparative terms the average infection of any given variety, with a possible maximum of 1,000, where 100 per cent of the plants in the row were infected with a maximum degree of 10. This method of computation has been used to indicate infection of the plants when in leaf and when heading. Infection data were taken when about 5 leaves were out, and again when the heads were well out of the boot.

As an example of the application of this method, take from Table III the data for Chul when grown as a winter wheat in 1917–18. The percentages of infected plants recorded for the first, second, and third replications are 80, 100, and 70, respectively, and the degrees of infection are 6, 6, and 3, respectively. The sum of the products of each per-

centage by the corresponding degree is 1,290. Dividing this sum by the number of replications, gives 430, which, therefore, is the average product representing the comparative susceptibility of Chul wheat, based on a possible maximum of 1,000 (Table IV).

In Table III, the percentage of plants infected and the degree of infection are shown for the 1917–18 season. The average susceptibility of each variety is shown in Table IV, not only for the first season, but for the seasons 1918–19 and 1919–20 as well.

Evidence of the varying susceptibility, even of strains within a variety, is shown in the case of the White Winter variety. In Table IV are listed five different C. I. numbers[5] of this variety. It will be noted that C. I. No. 5219 is somewhat susceptible, while three other strains are entirely immune, so far as those experiments show. The White Winter selection, C. I. No. 5222, which is quite susceptible, is also morphologically distinct from the other strains. These results emphasize the statement made by Vavilov (*19*) that workers should be careful to designate the exact botanical classification of host as well as parasite. Vavilov suggests that pure lines are desirable in studies of varietal susceptibility.

[5] Accession numbers of the Office of Cereal Investigations.

TABLE III.—*Data obtained on the percentage of plants infected and the degree of infection by Puccinia glumarum tritici on varieties of wheat, emmer, spelt, and einkorn at the fifth-leaf stage and at maturity in the fall of 1917 and the spring of 1918, at the Oregon Agricultural Experiment Station*

COMMON WHEATS

Group and variety.	C. I. No.	Fall sown.				Spring sown.			
		5th-leaf stage.		Heading.		5th-leaf stage.		Heading.	
		Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.
Hard red spring:									
Barletta (Minn. 1148)	3297					2	1	0	0
Cedar	4117					60	6	0	0
Chul	2406	80	6	95	5	90	7	Tr.	0
		100	6	100	4	75	7	Tr.	0
		70	3	85	4	80	7	0	0
Early Red Fife	4932	50	5	0	0				
		30	5	0	0				
		0	0	0	0				
Ghirka (Ghirka Spring)	1517					100	8	0	0
						80	8	0	0
						100	7	0	0
Haynes Bluestem	2874	0	0	0	0	70	4	0	0
		0	0	0	0	40	6	0	0
		0	0	0	0	15	4	0	0
Kinney	5197	0	0	0	0				
		0	0	0	0				
		0	0	0	0				
Kinney (Surprise)	5197	10	1	0	0				
		50	1	0	0				
		10	1	0	0				
Koo'a	2203	60	3	0	0	100	8	0	0
		70	3	10	0	80	7	100	0

Marquis	5???	0	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]
		0	0	0	0	[illegible]	[illegible]	0	0
		0	0	0	0	100	8	0	0
Pioneer	4324	20	1	T.	T.	10	6	0	0
		0	0	0	0	20	6	0	0
		0	0	0	0	60	8	0	0
Preston	3081	30	3	0	0	40	5	0	0
		2	4	0	0	30	3	0	0
		0	0	0	0	15	4	0	0
Hard red winter:									
Kanred	5146	0	0	0	0	80	6	0	0
		0	0	0	0	100	6	0	0
Kharkof	2193	0	0	0	0	...	...	...	...
		0	0	0	0	...	...	...	...
Turkey	1558	0	0	0	0	...	...	...	...
		0	0	0	0	...	...	...	...
		0	0	0	0	...	...	...	...
Soft red winter:									
Banner Berkeley		0	0	0	0	...	...	...	...
Fulcaster	3406	0	0	0	0	...	...	...	...
Fultz	3416	0	0	0	0	...	...	...	...
Gipsy (Farmers Friend)	5793	...	...	...	...	...	7	0	0
Golden Cross	5180	6	1	T.	2	...	...	...	...
		0	0	0	0	...	...	...	...
		0	0	0	0	...	...	...	...
Grandprize	4876	40	3	0	0	...	...	...	...
		80	6	0	0	...	...	...	...
		50	5	0	0	...	...	...	...
Harvest Queen	5314	10	1	T.	T.	...	...	...	...
		0	0	0	0	...	...	...	...
		0	0	0	0	...	...	...	...
Nebraska No. 28	5147	20	2	20	1	...	...	...	...
		0	0	0	0	...	...	...	...
Red Russian	4509	10	2	0	0	...	...	...	...
		20	2	0	0	...	...	...	...
		0	0	0	0	...	...	...	...
Zimmerman	2907	0	0	0	0	...	...	...	...

TABLE III.—*Data obtained on the percentage of plants infected and the degree of infection by Puccinia glumarum tritici on varieties of wheat, emmer, spelt, and einkorn at the fifth-leaf stage and at maturity in the fall of 1917 and the spring of 1918, at the Oregon Agricultural Experiment Station*—Continued

COMMON WHEATS—continued

Group and variety.	C. I. No.	Fall sown.				Spring sown.			
		5th-leaf stage.		Heading.		5th-leaf stage.		Heading.	
		Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.
White:									
Baart (Early Baart)	1697	50	2	80	3	100	8	0	0
		80	6	90	4	100	7	0	0
		20	3	15	2	100	8	0	0
Challenge (Webbs Challenge White)	4683	0	0	0	0	.....	.....	.....	.....
		0	0	0	0	.....	.....	.....	.....
		0	0	0	0	.....	.....	.....	.....
Dicklow	4758	0	0	0	0	10	2	.....	.....
						0	0	0	0
						0	0	.....	.....
Eaton	4682	0	0	0	0	.....	.....	.....	.....
		0	0	0	0	.....	.....	.....	.....
		0	0	0	0	.....	.....	.....	.....
Federation	4734	20	3	15	2	90	7	0	0
		10	3	0	0	75	7	0	0
		50	2	0	0	100	7	.....	.....
Florence	4170	.....	.....	.....	.....	50	4	0	0
						50	7	0	0
						20	0	0	0
Foisy	5253	0	0	0	0	.....	.....	.....	.....
		50	2	0	0	.....	.....	.....	.....
Goldcoin (American Banner)	5016	20	3	0	0	.....	.....	.....	.....
		10	2	0	0	.....	.....	.....	.....

Goldcoin (Fortyfold) (Wash. [illegible])	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	......	......	......	......
		40	2	0	0	......	......	......	......
		20	3	0	0	......	......	......	......
Jumbuck	4608	......	......	......	......	50	6	0	0
Pacific Bluestem	5231	......	......	......	......	100	8	0	0
						100	8	0	0
						100	8	0	0
Rink	5868	0	0	0	0	......	......	......	......
		0	0	0	0	......	......	......	......
		0	0	0	0	......	......	......	......
Royalton (Minn. 1037)	4968	......	......	......	......	0	0	0	0
Sonora	3036	0	0	0	0	......	......	......	......
		T.	T.	0	0	......	......	......	......
		0	0	0	0	......	......	......	......
Talimka	2495	100	5	100	5	100	8	T.	T.
		60	4	100	4	95	8	0	0
		50	4	40	2	100	8	0	0
White Winter	4684	0	0	0	0	......	......	......	......
		0	0	0	0	......	......	......	......
		0	0	0	0	......	......	......	......
Wilhelmina	4193	30	4	0	0	......	......	......	......
		0	0	0	0	......	......	......	......
		0	0	0	0	......	......	......	......
Miscellaneous:									
Hansia Broach	4690	100	9	100	3	100	9	50	5
		100	8	100	8	95	9	T.	T.
		100	7	100	5	100	8	T.	T.
Popatia Nadiad	4696	100	10	70	10	100	10	75	10
		100	9	100	8	100	9	T.	T.
		100	7	100	8	100	8	T.	T.
Tigharia	4564	......	......	......	......	100	7	50	2
						100	8	0	0
						100	8	0	0
Western Sweepstakes	5607	0	0	0	0	......	......	......	......

TABLE III.—*Data obtained on the percentage of plants infected and the degree of infection by Puccinia glumarum tritici on varieties of wheat, emmer, spelt, and einkorn at the fifth-leaf stage and at maturity in the fall of 1917 and the spring of 1918, at the Oregon Agricultural Experiment Station*—Continued

CLUB WHEATS

Group and variety.	C. I. No.	Fall sown.				Spring sown.			
		5th-leaf stage.		Heading.		5th-leaf stage.		Heading.	
		Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.
Dale (Dale Gloria)	4231	70	5	15	1	100	8	.....	.....
		20	2	0 8	0	80	9	.....	.....
		60	3	8	2	95	8	0	0
Hybrid 128	4512	0	0	0	0	.....	.....	.....	.....
		5	2	0	0	.....	.....	.....	.....
Hybrid 143	4160	0 0	0	0 0	0	.....	.....	.....	.....
		0	0	0	0	.....	.....	.....	.....
		0	0	0	0	.....	.....	.....	.....
Little Club	4219	40	5	10	1	.....	.....	.....	.....
		25	4	0	0	.....	.....	.....	.....
		60	3	3	1	.....	.....	.....	.....
Salt Lake Club	3018	20	3	15	2	.....	.....	.....	.....
		85	4	60	2	.....	.....	.....	.....
		75	4	60	3	.....	.....	.....	.....

POULARD WHEAT

Titanic	5535	0	0	0	0	.....	.....	.....	.....
		0	0	0	0	.....	.....	.....	.....
		10	2	0	0	.....	.....	.....	.....

Acme	5284					100	[illegible]	0	0
						100	8	0	0
						100	7	0	0
Arnautka	4064	10	1	0	0	50	6	0	0
		10	2	0	0	90	8	0	0
						30	8	0	0
Gharnovka	1443					100	7	0	0
						90	6	0	0
Iumillo	1736	10	2	0	0	70	8	0	0
		0	0	0	0	100	8	0	0
		0	0	0	0	90	5	0	0
Kubanka No. 8	4063	10	2	0	0	50	6	0	0
		0	0	0	0	20	6	0	0
		0	0	0	0	50	7	0	0
Marouani	2235					100	7	0	0
						100	8	0	0
Mindum (Minn. 470)	5296					100	8	0	0
EMMER									
Brown Winter	2483	0	0	0	0				
Khapli	4013					60	6	0	0
						80	7	0	0
Vernal (White Spring) (Minn. 1165)	3686					10	7	0	0
Vernal (White Spring)	1522					100	8	0	0
Do	1524					100	8	0	0
						90	7	0	0
						100	8	0	0
Do	4781					90	8	0	0
						100	8	0	0

TABLE III.—*Data obtained on the percentage of plants infected and the degree of infection by Puccinia glumarum tritici on varieties of wheat, emmer, spelt, and einkorn at the fifth-leaf stage and at maturity in the fall of 1917 and the spring of 1918, at the Oregon Agricultural Experiment Station*—Continued

Group and variety.	C. I. No.	Fall sown.				Spring sown.			
		5th-leaf stage.		Heading.		5th-leaf stage.		Heading.	
		Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.	Plants infected, per cent.	Degree of infection.
SPELT									
Red Winter	1772	0	0	0	0	.....	.....	.....	.....
POLISH WHEAT									
Polish	5524	.....	.....	.....	.....	50	6	0	0
						50	8	0	0
						50	7	0	0
EINKORN									
Einkorn	2433	.....	.....	.....	.....	0	0	0	0

TABLE IV.—*Data showing the susceptibility of varieties of wheat, emmer, spelt, and einkorn to infection by Puccinia glumarum (tritici) as determined by records taken when the plants, grown in the nursery, were developing the fifth leaf and when they were heading, in one or more of the three years from 1918 to 1920, inclusive, at the Oregon Agricultural Experiment Station, Corvallis, Oreg.*

COMMON WHEATS

Group and variety.	C. I. No.	Varietal susceptibility.											
		1917–1918				1918–1919				1919–1920			
		Fall sown.		Spring sown.		Fall sown.		Spring sown.		Fall sown.		Spring sown.	
		5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.
Hard red spring:													
Barletta (Minn. 1148)	3297			2	0	0	0			0	0	0	0
Cedar	4117			360	0	0	0			0	0	T.	0
Chul (Alturas, Calif.)	2227					293	594			0	T.	40	0
Chul	2227					133	792			0	0	30	0
Chul (Yantagbay)	2404					135	700			T.	0	160	75
Chul	2406	430	405	572	T.	830	792	125	0	50	T.	360	0
Early Red Fife	4932	133	0			0	0			0	0	0	0
Ghirka (Ghirka Spring)	1517			773	0	0	15	50	0	0	0	3	0
Haynes Bluestem	2874	0	0	193	0	0	0	3	0	0	0	0	0
Humpback	3690					35	0			0	0	0	0
Huron	3315					0	0			0	0	0	0
Kinney	5197	0	0			T.	0			0	0	80	0
Kinney (Surprise)	5197	23	0			20	20			0	0	250	0
Koola	2203	367	7	687	0	60	60	425	0	1	0	1	0
Marquis	3641	0	0	497	0	5	5	1	0	0	0	T.	0
Marquis (Minn. 1239)	3041					T.	0			0	0	T.	0
Pioneer	4324	7	T.	220	0	0	0	1	0	0	0	T.	0
Preston (Minn. 924)	2958					0	0			0	0	0	0
Preston	3081	33	0	117	0	0	0	1	0	0	0	0	0

TABLE IV.—*Data obtained on the susceptibility of varieties of wheat, emmer, spelt, and einkorn to infection by Puccinia glumarum tritici as determined by records taken when the plants, grown in the nursery, were developing the fifth leaf and when they were heading, in one or more of the three years from 1918 to 1920, inclusive, at the Oregon Agricultural Experiment Station, Corvallis, Oreg.*—Continued

COMMON WHEATS—continued

Group and variety.	C. I. No.	Varietal susceptibility.											
		1917–1918				1918–1919				1919–1920			
		Fall sown.		Spring sown.		Fall sown.		Spring sown.		Fall sown.		Spring sown.	
		5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.
Hard red winter:													
Kanred	5146	0	0	540	0	0	0	.....	.....	0	0	75	.....
Kharkof	2193	0	0	.....	.....	0	0	.....	.....	T.	0	50	0
P–1066 (Kansas)	5879	.....	.....	.....	.....	8	30	.....	.....	0	0	140	.....
P–1068 (Kansas)	5880	.....	.....	.....	.....	0	0	.....	.....	0	0	90	.....
Turkey	1558	0	0	.....	.....	100	10	.....	.....	0	0	5	0
Soft red winter:													
Banner Berkeley	.....	0	0	.....	.....	25	0	50	0	0	0	0	.....
Fulcaster	3406	0	0	.....	.....	35	0	160	0	0	0	25	.....
Fultz	3416	0	0	.....	.....	60	0	10	0	0	0	T.	.....
Fultz (Economy)	3397	.....	.....	.....	.....	315	285	.....	.....	180	0	800	.....
Gipsy (Farmers Friend)	5793	.....	.....	.....	0	.....	.....	.....	.....	.....	.....	.....	.....
Golden Cross	5180	2	1	0	0	53	500	.....	.....	0	0	0	.....
Grandprize	4876	283	0	.....	.....	681	250	.....	.....	T.	0	760	0
Harvest Queen	5314	3	T.	.....	.....	T.	0	.....	.....	.....	.....	T.	0
Illini Chief	5406	T.	.....	.....	.....	78	10	160	0	0	0	100	.....
Jones Fife	3452	.....	.....	.....	.....	471	100	.....	.....	1	0	250	.....
Jones Fife	4408	.....	.....	.....	.....	405	100	.....	.....	1	0	175	.....
Jones Fife	4468	.....	.....	.....	.....	225	60	.....	.....	2	0	300	.....
Jones Fife (Super)	5841	.....	.....	.....	.....	384	50	420	0	50	0	550	.....
Jones Fife	6008	.....	.....	.....	.....	340	55	.....	.....	10	0	200	.....
Jones Fife	6027	.....	.....	.....	.....	280	50	.....	.....	10	0	200	.....

Mealy	3358	[illegible]	[illegible]	...	...	[illegible]	[illegible]	...	...	T.	[illegible]	[illegible]	[illegible]
Nebraska No. 28	5147	20	10	...	...	[illegible]	10	...	...	[illegible]	[illegible]	[illegible]	...
Ohio Hybrid 702	5378	...	...	...	...	493	100	...	...	95	0	[illegible]	...
Ohio Hybrid 703	5379	...	...	...	...	373	300	...	...	95	0	[illegible]	...
Prosperity	5937	...	...	...	...	597	75	...	...	150	0	800	...
Prosperity (American Bronze)	5638	...	...	...	...	382	90	...	...	75	0	270	...
Purdue No. 1	4871	...	...	...	...	850	700	...	...	600	0	950	...
Quadruple (Wash. 601)	6466	...	...	...	...	0	0	...	...	T.	0	25	...
Red Russian	4509	20	0	...	...	5	T.	...	...	0	0	0	...
Red Russian (Wash. 270)	4509	...	...	...	...	0	0	...	...	0	0	0	...
Ruddy	6465	...	...	...	...	0	0	...	...	0	0	0	...
Stoner	2980	...	...	...	...	305	270	...	...	1	0	475	...
Triplet (Wash. 597)	5408	...	...	...	...	T.	0	...	...	0	0	0	0
Zimmerman	2907	0	0	...	...	45	0	T.	0	0	0	30	...
White:													
Allen (Red Allen)	5407	...	...	...	...	25	40	...	...	0	0	40	0
Arcadian (Early Arcadia)	4220	...	...	...	...	325	160	...	...	80	0	700	...
Do	5536	...	...	...	...	498	400	...	...	170	0	800	...
Do	5940	...	...	...	...	488	500	...	...	75	0	686	...
Baart (Early Baart)	1697	213	210	767	0	195	70	375	20	50	0	300	0
Challenge (Webbs Challenge White)	4683	0	0	...	...	T.	0	...	...	0	0	...	...
Dicklow	4758	0	0	7	0	30	T.	75	0	0	0	0	0
Eaton	4682	0	0	...	...	3	0	...	...	0	0	100	0
Federation	4734	63	10	618	0	99	3	...	...	T.	0	570	0
Florence	4170	...	...	223	0	475	10	...	...	0	0	T.	0
Foisy	5253	53	0	...	...	1	0	...	...	0	0	50	0
Genesee Giant	1744	...	...	...	...	...	...	...	...	200	0	...	...
Goldcoin (American Banner)	3016	30	0	...	...	520	700	450	0	T.	0	600	...
Goldcoin (Fortyfold)	4156	...	...	...	...	270	0	...	...	0	0	180	0
Goldcoin (Fortyfold) (Wash. 351)	6176	60	0	...	...	25	0	...	...	0	0	250	...
Jumbuck	4608	...	...	300	0	0	0	...	...	0	0	T.	0
Kofod	2907	...	...	...	...	0	0	...	...	0	0	0	0
Link (Missing Link)	4866	...	...	...	...	38	100	...	...	0	0	140	0
Martin (Martin Amber)	5925	...	...	...	...	38	20	...	...	T.	0	350	...
Pacific Bluestem	5231	...	...	800	0	155	35	130	0	0	0	20	0
Prohibition	5223	...	...	...	...	45	0	...	...	T.	0	20	0
Rink	5218	...	...	...	...	0	0	...	...	0	0	0	...
Rink	5868	0	0	...	...	T.	T.	...	...	0	0	T.	0
Royalton (Minn. 1037)	4968	...	...	0	0	0	0	...	...	0	0	0	0

TABLE IV.—*Data obtained on the susceptibility of varieties of wheat, emmer, spelt, and einkorn to infection by Puccinia glumarum tritici as determined by records taken when the plants, grown in the nursery, were developing the fifth leaf and when they were heading, in one or more of the three years from 1918 to 1920, inclusive, at the Oregon Agricultural Experiment Station, Corvallis, Oreg.*—Continued

COMMON WHEATS—continued

Group and variety.	C. I. No.	Varietal susceptibility.											
		1917–1918				1918–1919				1919–1920			
		Fall sown.		Spring sown.		Fall sown.		Spring sown.		Fall sown.		Spring sown.	
		5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.
White—Continued.													
Satisfaction (Smith's Rustproof)	3588	.....	.....	.....	.....	110	240	.....	.....	0	0	140	.....
Sonora	3036	T.	0	.....	.....	25	0	.....	.....	T.	0	T.	0
Do	4293	.....	.....	.....	.....	0	T.	.....	.....	0	0	0	0
Do	4501	.....	.....	.....	.....	0	0	.....	.....	0	0	0	0
Talimka	2495	313	327	787	T.	289	490	136	150	T.	0	200	95
White Winter	4684	0	0	.....	.....	.....	.....	.....	.....	T.	0	200	0
Do	5219	.....	.....	.....	.....	33	5	.....	.....	0	0	0	.....
Do	5224	.....	.....	.....	.....	0	0	.....	.....	0	0	0	.....
Do	5232	.....	.....	.....	.....	0	0	.....	.....	0	0	0	.....
White Winter selection	5222	.....	.....	.....	.....	206	360	.....	.....	5	0	800	0
Wilhelmina	4193	40	0	.....	.....	0	0	.....	.....	0	0	0	0
Winter Bluestem	5409	.....	.....	.....	.....	0	T.	.....	.....	0	0	0	.....
Miscellaneous:													
Hansia Broach	4690	800	533	852	83	750	900	230	300	60	0	150	50
Turkey x Chul (F_3, No. 1)	.....	.....	.....	.....	.....	3	100	.....	.....	T.	0	480	0
Do. (F_3, No. 2)	.....	.....	.....	.....	.....	270	190	.....	.....	0	0	350	0
Do. (F_3, No. 3)	.....	.....	.....	.....	.....	35	140	.....	.....	0	0	420	.....
Little Joss	6730	.....	.....	.....	.....	0	0	.....	.....	0	0	0	.....
Popatia Nadiad	4096	867	557	900	250	900	800	580	600	250	T.	800	300
Tigharia	4504	.....	.....	767	33	7.38	150	.....	.....	0	0	T.	.....
Trimenia	2411	.....	.....	.....	.....	0	0	.....	.....	0	0	280	.....
Western Sweepstakes	4805	0	0	.....	.....	T.	0	.....	.....	0	0	280	.....

					CLUB WHEATS								
Coppei	4238					5	0			T.	0	285	0
Dale (Dale Gloria)	4231	190	20	760	0	693	570			20	0	550	0
Hybrid 60	5024					0	0			0	0	T.	0
Hybrid 123	4511					5	0			1	0	30	0
Hybrid 128	4512					0	0			0	0	T.	
Hybrid 128	4512	3	0			48	20			T.	0	270	0
Hybrid 143	4160	0	0			0	0	0	0	0	0	T.	0
Hybrid 143	4513					0	0	175	0	T.	0	T.	0
Little Club (Wash. 500)	4237					3	30			0	0	150	0
Little Club	4219	160	4			10	150			T.	0	10	0
Mayview	5874					0	0			0	0	T.	0
Salt Lake Club	3018	233	110			95	360			T.	0	10	0
					POULARD WHEAT								
Titanic	5535	7	0			25	0			0	0	0	
					DURUM WHEATS								
Acme	5284			767	0								
Arnautka	4064	15	0	420	0	25	238		0	0	0	0	0
Arnautka (Speltz Mars) (Minn. 337)	6236					23	0			0	0	10	0
Do	6236					48	0	180	0	0	0	30	0
Gharnovka	1443			620	0	10	120			0	0	100	0
Iumillo	1736	7	0	603	0	83	50	120	T.	0	0	T.	0
Kubanka	2094					0	0			0	0	T.	0
Kubanka No. 8	4063	7	0	257	0	80	4	121	10	0	0	T.	0
Marouani	2235			750	0	T.	0			0	0	450	0
Mindum (Minn. 470)	5296			800	0	96	0	396	0	0	0	75	0
Pentad (D-5)	3322									0	0	60	0

TABLE IV.—*Data obtained on the susceptibility of varieties of wheat, emmer, spelt, and einkorn to infection by Puccinia glumarum tritici as determined by records taken when the plants, grown in the nursery, were developing the fifth leaf and when they were heading, in one or more of the three years from 1918 to 1920, inclusive, at the Oregon Agricultural Experiment Station, Corvallis, Oreg.*—Continued

Group and variety.	C. I. No.	Varietal susceptibility.											
		1917–1918				1918–1919				1919 1920			
		Fall sown.		Spring sown.		Fall sown.		Spring sown.		Fall sown.		Spring sown.	
		5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.	5-leaf stage.	Heading.
EMMER													
Brown Winter	2483	0	0	.....	.....	T.	0	.....	.....	0	0	760	.....
Khapli	4013	.....	.....	460	0	0	0	.....	.....	0	0	40	0
Vernal (White Spring) (Minn. 1165)	3686	.....	.....	163	0	0	0	40	0	0	0	0	0
Vernal (White Spring)	1522	.....	.....	800	0	.....	.....	.....	.....	.....	.....	.....	.....
Do	1524	.....	.....	743	0	0	0	333	0	0	0	10	0
Do	4781	.....	.....	760	0	.....	.....	.....	.....	.....	.....	.....	.....
Do	4781	.....	.....	.....	.....	0	0	347	0	0	0	0	0
SPELT													
Red Winter	1772	0	0	.....	.....	0	0	.....	.....	0	0	0	.....
POLISH WHEAT													
Polish	5524	.....	.....	350	0	0	0	.....	.....	0	0	0	0
EINKORN													
Einkorn	2433	.....	.....	0	0	0	0	.....	.....	0	0	0	0

ADDITIONAL FIELD DATA

In addition to the information tabulated above on susceptibility of varieties in the rust nursery at Corvallis, Oreg., during the three seasons, many valuable field notes were recorded at various times and places where rust infection had developed under natural conditions.

At the Sherman County Branch Station, at Moro, Oreg., where extensive sowings of wheat varieties are made each year, there was a severe outbreak of stripe rust in the spring of 1919. This afforded an excellent opportunity to obtain data on the comparative susceptibility of some of the leading varieties of wheat grown at that station in 1919. The following table shows the ratings of these varieties, using the system of grading explained for Tables III and IV. The notes, taken just before the plants headed, are recorded in Table V.

TABLE V.—*Data showing the susceptibility of commercial wheat varieties to infection by stripe rust at the Sherman County Branch Station, Moro, Oreg., in 1919*

Variety.	C. I. No.	Varietal susceptibility.
Turkey	1558	425
Do	1571	410
Do	1756	325
Do	2998	415
Turkey (Local)	4429	390
Kanred	5146	525
Argentine	1569	560
Crimean	1437	510
Alberta Red	2979	675
Beloglina	2239	710
Theiss	1501	105
Nebraska No. 28	5147	355
Kharkof	5549	250
Jones Fife	6177	855
Hybrid 128	4512	630
Goldenin (Fortyfold)	4156	635

During the season of 1919 notes were taken also on the stripe rust occurring on a number of wheat varieties growing at Moscow in the plots of the agronomy department of the University of Idaho. The notes were taken on June 20, when the grain was mostly headed. Apparently the rust was just beginning to appear at that time and, as no opportunity presented itself to inspect this grain again, it is not known that the figures in Table VI represent the maximum rust infection which appeared on these plots during that season. At any rate, they give some indication of the most susceptible varieties.

TABLE VI.—*Data showing susceptibility of wheat varieties to stripe rust after heads had appeared, when grown in plats at the University of Idaho, Moscow, in 1919*

Variety.	C. I. No.	Varietal susceptibility
Prohibition	4068	
Challenge (Webbs Challenge White)	4683	
Rink	5868	
White Winter	4684	
Defiance	4354	
Pacific Bluestem	3019	
Kinney	5189	
Red Russian	4509	
Fultz	3416	
Marquis	3641	
Dawson (Dawson Golden Chaff)	4480	Trace
Early Arcadia	4220	
Red Wave	3500	
Poole	3488	
Poole (Harvest King)	4894	
Jones Fife	3452	
Haynes Bluestem	2874	
Sonora	4293	
Baart (Early Baart)	1697	Trace
Stoner	2980	
Golden Cross	5180	
Kharkof	1442	
Preston	2938	
Hybrid 63	4157	Trace

During the summer of 1920 there was an outbreak of stripe rust in the wheat classification nursery at Corvallis, Oreg. Table VII shows the comparative susceptibility of some of the varieties as indicated by the rust infection which appeared on them after the plants were all headed.

TABLE VII.—*Data showing susceptibility of wheat varieties to stripe rust when grown in the wheat classification nursery at Corvallis, Oreg., in 1920*

COMMON WHEATS

Group and variety.	C. I. No.	Varietal susceptibility.
Hard red spring:		
Chul	2227	
Early Red Fife	4932	
Haynes Bluestem	2874	
Humpback	3690	
Huston	3208	
Kinney	5189	
Marquis	3641	
Pioneer	4324	
Prelude	4323	
Preston	3328	
Preston (Velvet Chaff)	3318	
Hard red winter:		
Alton (Ghirka Winter)	1438	
Beloglina	1667	
Kanred	5146	
Kharkof	1442	
Turkey	1558	

TABLE VII.—*Data showing susceptibility of wheat varieties to stripe rust when grown in the wheat classification nursery at Corvallis, Oreg., in 1920*—Continued

COMMON WHEATS—continued

Group and variety.	C. I. No.	Varietal susceptibility.
Soft red winter:		
Climax (Jones Climax)	6203	275
Currell	3320	70
Currell (Golden Chaff)	5578	00
Diamond Grit	3385	100
Fulcaster	3406	50
Fultz	3410	150
Gipsy (Defiance)	5305	0
Goldencross	5180	T.
Grandprize	4876	400
Harold	6005	600
Harvest Queen	5314	0
Harvest Queen (Red Cross)	4882	0
Illini Chief	5400	0
Jones Fife	4468	250
Jones Fife (Super)	5544	600
Jones Longberry	5339	0
Leap	4823	0
Lofthouse	3275	0
Mealy	3358	20
Nebraska No. 28	5147	100
New Columbia	5916	20
Poole	3488	900
Poole (Harvest King)	5680	570
Prosperity (American Bronze)	5380	125
Red Clawson (Early Red Clawson)	3393	550
Red May	5336	20
Red May (Early Harvest)	4334	20
Red May (Early Ripe)	3394	150
Red May (Michigan Amber)	1069	0
Red May (Enterprise)	4854	T.
Red Russian	4509	0
Red Wave	3500	250
Rural New Yorker No. 6	5921	0
Rural New Yorker No. 57	3516	50
Squarehead	5234	0
Stoner	2980	0
Triplet	5408	0
Zimmerman	2907	0
White:		
Bearded Winter Fife	4204	100
Bobs	4990	T.
Challenge (Webbs Challenge White)	4683	0
Dawson Goldenchaff	3342	50
Defiance	4347	5
Dicklow	3663	0
Early Arcadia	3390	125
Eaton	5682	0
Foisy	5242	0
Genesee Giant	1744	300
Goldcoin	2096	50
Gypsum (Colorado Special)	4762	0
Hard Federation	4980	0
Jumbuck	4608	0
Kofod	4337	0
New Zealand	6011	5
Oatka Chief	3481	300

TABLE VII.—*Data showing susceptibility of wheat varieties to stripe rust when grown in the wheat classification nursery at Corvallis, Oreg., in 1920*—Continued

Group and variety.	C. I. No.	Variety susceptibility
COMMON WHEATS—continued		
White—Continued.		
Pacific Bluestem	4067	
Prohibition	4068	
Rink	5868	
Satisfaction	5938	
Satisfaction (Smith's Rustproof)	3588	
Seneca Chief	3575	
Silvercoin	6013	
Sonora	3036	
Sunset	6253	
Surprise (White Russian)	5277	
Talimka	2495	
White Australian	3019	
White Federation	4981	
White Winter	5219	
CLUB WHEATS		
Big Club	4257	
Bluechaff	5256	
Brown Glory	4240	
Coppei	3088	
Dale (Dale Gloria)	4155	
Hybrid 60	5024	
Hybrid 108	5025	
Hybrid 123	4511	
Hybrid 128	4512	
Jenkin	5177	
Little Club	4066	
Mayview	5874	
Redchaff	4241	
MISCELLANEOUS WHEATS		
Alaska (poulard)	5988	
Arnautka (durum)	1494	
Einkorn	2433	
Khapli emmer	4013	
Kubanka (durum)	1440	
Mindum (durum)	5296	
Red Winter spelt	1772	
Vernal (White Spring) emmer	1524	
White Spring spelt	2968	

GREENHOUSE EXPERIMENTS

The greenhouse studies on susceptibility of grain varieties to stripe rust were carried out in a wing of the greenhouse at the Oregon Agricultural Experiment Station, at Corvallis. The methods used were the same as previously outlined in the investigation of specialized races.

The results of the inoculations made in the greenhouse during the three seasons, 1917–18, 1918–19, and 1919–20, using 92 different varieties and strains of wheat, are embodied in Table VIII. The method used in computing data has already been explained in connection with Tables III and IV.

TABLE VIII.—*Data on susceptibility of varieties of wheat, emmer, spelt, and einkorn to stripe rust, including the number of separate experiments made each season and in all seasons, the number of plants inoculated and the number infected in each season and in all three seasons, and the annual and average degree of infection, when the plants were grown in the greenhouse at Corvallis, Oreg., in the three seasons, 1917–18, 1918–19, and 1919–20*

COMMON WHEATS

Group and variety.	C. I. No.	1917–18				1918–19				1919–20				Totals.			
		Number of—			Character of infection.	Number of—			Character of infection.	Number of—			Character of infection.	Number of—			Character of infection.
		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.	
Hard red spring:																	
Barletta (Minn. 1148)	3297	.....	.....	.....	.....	3	36	4	0	.....	.....	.....	.....	3	36	4	0
Cedar	4117	.....	.....	.....	.....	1	15	13	2	4	43	21	3	5	58	34	2–3
Chul	2227–1	.....	.....	.....	.....	.....	.....	.....	.....	2	20	11	4	2	20	11	4
Chul (Yantagbay)	2404	.....	.....	.....	.....	.....	.....	.....	.....	2	20	4	2–3	2	20	4	2–3
Chul	2406	1	12	10	4	9	187	98	4	26	240	152	4	36	439	260	4
Dakota No. 5	.....	1	15	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	15	0	0
Dakota No. 7	.....	1	20	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	20	0	0
Ghirka (Ghirka Spring)	1517	.....	.....	.....	.....	1	13	2	1	2	20	10	1	3	33	12	1
Haynes Bluestem	2874	.....	.....	.....	.....	1	24	1	1	2	19	4	2	3	43	5	1–2
Kinney	5197	.....	.....	.....	.....	1	10	0	0	.....	.....	.....	.....	1	10	0	0
Do	5197	.....	.....	.....	.....	.....	.....	.....	.....	1	10	0	0	1	10	0	0
Koola	2203	1	15	10	4	2	29	21	3–4	.....	.....	.....	.....	3	44	31	3–4
Marquis	3641	.....	.....	.....	.....	.....	.....	.....	.....	3	33	14	4	3	33	14	4
Pioneer	4234	.....	.....	.....	.....	1	14	0	0	.....	.....	.....	.....	1	14	0	0
Preston	3081	.....	.....	.....	.....	1	20	0	0	3	30	0	0	4	50	0	0
Red Fife	4932	.....	.....	.....	.....	1	14	0	0	2	20	0	0	3	34	0	0
Hard red winter:																	
Kanred	5146	2	33	33	4	9	158	47	4	3	50	17	3–4	14	241	97	3–4
Kharkof	2103	.....	.....	.....	.....	1	20	10	2	2	20	2	4	3	40	12	3–4

P-1066	5870									[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
P-1068	5880									2	25	6	3	2	25	6	[illegible]
Turkey	1558	1	16	0	0	5	46	12	4	3	36	10	4	9	98	22	4
Soft red winter:																	
Banner Berkeley						1	36	11	4					1	36	11	4
Fulcaster	3406					2	44	14	3-4					2	44	14	3-4
Fultz	3416					1	19	0	0					1	19	0	0
Goldencross	4564					1	22	0	0	3	30	0	0	4	52	0	0
Grandprize	4876					1	12	8	4	2	20	14	4	3	32	22	4
Harvest Queen	5314									2	20	0	0	2	20	0	0
Illini Chief	5406					1	26	0	0	2	20	0	0	3	46	0	0
Jones Fife	3452									2	30	2	4	2	30	2	4
Do.	4468	1	18	15	4	4	70	34	4	4	61	9	4	9	149	58	4
Do.	4468									2	20	2	1-2	2	20	2	1-2
Do.	5608									3	30	7	4	3	30	7	4
Nebraska No. 28	5147					1	17	9	4					1	17	9	4
Purdue No. 1	4871									3	33	20	2-4	3	33	20	2-4
Red Russian	4509					1	12	0	0	1	10	0	0	2	22	0	0
Red Russian (Wash. 270).	4509									1	10	0	0	1	10	0	0
Squarehead	5234					1	29	0	0	2	20	0	0	3	49	0	0
Stoner	2980					1	17	11	4	2	30	5	4	3	47	16	4
Zimmerman	2907					1	17	0	0					1	17	0	0
White:																	
Arcadian (Early Arcadia).	4220									3	27	9	4	3	27	9	4
Baart (Early Baart)	1697	2	35	32	4	5	82	62	4	6	69	23	4	13	186	117	4
Bobs	2826					1	27	15	3	3	20	3	2	4	47	18	2-3
Dicklow	4758					1	23	0	0	4	40	0	5	5	63	0	0
Eaton	4682					1	13	0	0	2	20	0	0	3	33	0	0
Federation	4734					1	18	10	4	2	20	6	3	3	38	16	3-4
Florence	4170					2	22	8	0					2	22	8	0
Foisy	5253									2	20	1	2	2	20	1	2
Goldcoin (American Banner).	3016					2	40	36	3-4	5	36	19	4	7	96	55	3-4
Goldcoin (Fortyfold)	4156									4	41	8	3	4	41	8	3

TABLE VIII.—*Data on susceptibility of varieties of wheat, emmer, spelt, and einkorn to stripe rust, including the number of separate experiments made each season and in all seasons, the number of plants inoculated and the number infected in each season and in all three seasons, and the annual and average degree of infection, when the plants were grown in the greenhouse at Corvallis, Oreg., in the three seasons, 1917–18, 1918–19, and 1919–20*—Continued

COMMON WHEATS—continued

Group and variety.	C. I. No.	1917–18				1918–19				1919–20				Totals.			
		Number of—			Character of infection.	Number of—			Character of infection.	Number of—			Character of infection.	Number of—			Character of infection.
		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.	
White—Continued.																	
Pacific Blu st	5231					1	17	2	2	2	20	1	2	3	37	3	2
Rink	5865									5	50	33	2	5	50	33	2
Royalton (Minn. 1037)	4968	1	8	1	1									1	8	1	1
Sonora	3036	1	68	4	1	6	42	11	1	3	30	2	1	10	140	17	1
Do	4293					1	18	0	0	2	17	0	0	2	35	0	0
Do	4501									2	20	0	0	2	20	0	0
Talimka	2495	1	35	27	4	5	79	62	4	35	983	451	4	41	1,097	540	4
White Winter	4684									1	10	0	0	1	10	0	0
Do	5232									2	23	0	0	2	23	0	0
Wilhelmina	4193					1	13	0	0	3	34	0	0	4	47	0	0
Miscellaneous:																	
Black Persian	2442	1	10	4	3									1	10	4	3
Chul x Turkey						2	55	40	4					2	55	40	4
Hansia Broach	4690									3	39	22	4	3	39	22	4
Popatia Nadiad	4696	1	14	14	4	7	76	35	4	1	11	2	4	9	101	51	4
Western Sweepstakes	5607					1	23	21	4	2	20	2	3	3	43	23	3·4

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CLUB WHEATS																	
Dale (Dale Gloria)	4251	1	27	23	4	2	46	25	4	3	27	5	3	6	100	53	3–4
Hybrid 128	4512					1	17	13	4					1	17	13	4
Hybrid 143	4100									2	20	1	2	2	20	1	2
Little Club	4219	1	38	26	4	2	24	9	4	4	53	8	4	7	115	43	4
Salt Lake Club	3018					1	25	22	4					1	25	22	4
POULARD WHEAT																	
Titanic	5535					1	13	5	0	2	20	4	2	3	33	9	0–2
DURUM WHEATS																	
Arnautka	4064					1	16	15	4	1	10	0	0	2	26	15	4
Arnautka (Speltz Mars)	6236					1	4	2	4					1	4	2	4
Beloturka	1513									2	20	4	2	2	20	4	2
Black Don	2100	1	15	12	4									1	15	12	4
Iumillo	1736	1	13	8	2	1	26	4	2	3	30	10	1	5	69	22	1–2
Kubanka No. 8	4063	2	41	39	4	1	22	6	4					3	63	45	4
Marouani	2235	1	15	13	4									1	15	13	4
EMMER																	
Black Winter	2337	2	46	42	4					2	19	9	4	4	65	51	4
Brown Winter	2483	2	43	40	4	2	14	7	4					4	57	47	4
Khapli	4013	1	11	0	0									1	11	0	0
Vernal	1522	1	16	15	2									1	16	15	2
Do	1524	1	15	10	2									1	15	10	2
Do	1526	1	35	35	2									1	35	35	2
Do	4781	1	30	24	1									1	30	24	1
Vernal (Minn. 1165)	3686	3	69	33	0–1									3	69	33	0–1

TABLE VIII.—*Data on susceptibility of varieties of wheat, emmer, spelt, and einkorn to stripe rust, including the number of separate experiments made each season and in all seasons, the number of plants inoculated and the number infected in each season and in all three seasons, and the annual and average degree of infection, when the plants were grown in the greenhouse at Corvallis, Oreg., in the three seasons, 1917–18, 1918–19, and 1919–20*—Continued

Group and variety.	C. I. No.	1917–18				1918–19				1919–20				Totals.			
		Number of—			Character of infection.	Number of—			Character of infection.	Number of—			Character of infection.	Number of—			Character of infection.
		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.		Experiments.	Plants inoculated.	Plants infected.	
SPELT																	
Red Winter	1772	1	30	1	2	.....	.....	.....	.....	.....	.....	.....	.....	1	30	1	2
EINKORN																	
Einkorn	2433	1	20	0	0	.....	.....	.....	.....	.....	.....	.....	.....	1	20	0	0
Do	2973	1	24	20	1	.....	.....	.....	.....	.....	.....	.....	.....	1	24	20	1

NURSERY AND GREENHOUSE RESULTS COMPARED

Table IX presents a comparison of the results obtained in both the nursery and greenhouse with certain varieties which have proved very resistant in all these trials. No varieties are listed unless they were grown three seasons in the nursery and tested for resistance there.

TABLE IX.—*Data showing summarized results of nursery and greenhouse experiments on susceptibility of wheat varieties to infection by P. glumarum tritici*

Variety.	C. I. No.	Nursery.		Greenhouse.	
		Number of experiments.	Average susceptibility.	Number of experiments.	Character of infection.
Baletta	3207	4	0. 5	3	0
Dicklow	4758	8	12	5	0
Foisy	5253	6	17	2	2
Fulcom	2433	4	0	1	0
Fultz	3416	5	14	1	0
Harvest Queen	5314	4	1	2	0
Haynes Bluestem	2874	6	33	3	1–2
Kharkof	2193	5	10	3	2–3
Kinney	5197	6	Trace.	1	0
Preston	3081	10	15	4	0
Wilhelmina	4193	6	6	4	0
Early Red Fife	4932	6	22	3	0
Red Russian	4509	6	4	2	0
Red Winter spelt	1772	5	0	1	1
Rink	5868	6	Trace.	5	2
Rovalton	4968	6	0	1	1
Sonora	3036	6	4	10	1
Challenge (Webbs Challenge White)	4683	6	Trace.		
White Winter	4684	6	Trace.	1	0

As shown by Tables III to IX, there has been a marked difference in susceptibility to stripe rust in the different varieties of wheat. Further study doubtless will show whether there are strains of the rust which are able to attack some of these varieties which have proved resistant to the strains which have been under observation. The difference in susceptibility to stripe rust in the various varieties of wheat which have been studied seems to be much more marked than in the case of either stem rust or leaf rust.

Various European workers have referred to this very marked difference in susceptibility to *P. glumarum* as it appears in Europe. Henning (*8*) states in this connection, "The economic importance of the yellow rust has recently, in our country (Sweden), been considered rather inferior, since we, in the latter part of the nineteenth century, have demonstrated that the different varieties of wheat show a very unlike susceptibility to this disease; moreover, we have succeeded in producing varieties, by means of crossing, which possess a marked power of resistance toward yellow rust. However, we have learned recently that this power of resistance is quite variable, so that we must give some further attention to this kind of rust."

Comparatively few of the different varieties studied showed infection in the heads. This is the type of infection which is the most destructive, as the yield may be very materially reduced when the heads become infected. A discussion of this type of injury was given in one of the earlier papers of this series (*10*). It also is noteworthy that few of the wheat varieties which are commonly grown in the western portion of the United States where stripe rust is found are very susceptible to the rust. Exceptions to this are several of the club varieties, Early Baart, Jones Fife, and a few others.

A study of the foregoing results also will show that the varieties which have proved more or less resistant to leaf rust and stem rust have not shown, in every case, a similar resistance to stripe rust. Notable examples of this are several of the durum wheats which have been shown to be resistant to most strains of *Puccinia graminis tritici*. Khapli (C. I. 4013), an emmer which Hayes, Parker, and Kurtzweil (*6*) found resistant to all biologic forms of stem rust thus far isolated, is not especially resistant to the strains of stripe rust with which it has been inoculated. Jenkin and Sampson (*11*) state that comparatively few of the wheat varieties which they tested were resistant to both black rust (Puccinia graminis) and yellow rust (Puccinia glumarum).

Hiltner (*9*, *p. 83*) reports that in Germany spring wheat suffers more than winter wheat from the attack of *P. glumarum*. He also states that the club varieties as a class appear to be especially susceptible and that those varieties with broad leaves were not so often attacked by the rust. Von Kirchner (*12*) gives 20.4 per cent as the average stripe-rust infection on winter wheat for a number of years, while spring wheat for the same number of years showed only 16.2 per cent infection. Jenkin and Sampson (*11*) state that autumn varieties were found to be more susceptible to black rust and the spring varieties to yellow rust. Schneiderhan, in the unpublished report of the Sherman County Branch Station, Moro, Oreg., for 1916, reports that when certain varieties were grown as both spring and winter wheats, those sown in the fall developed the larger percentages of infection of stripe rust.

Examination of Tables III and IV shows that leaf infection in the seedling stage usually was much greater in spring-sown wheat. Infection at heading time, on the contrary, was in most cases much greater in winter wheat. It seems reasonable to suppose that both seasonal and regional differences in climate will determine to a certain extent whether fall-sown or spring-sown wheat becomes more heavily infected with stripe rust.

Histological studies of resistant and susceptible varieties of wheat attacked by stripe rust have not been made. The general external macroscopic evidences of resistance appear to be similar to those described by Stakman (*17*) for *Puccinia graminis tritici* E. and H. and by Parker (*15*) for *Puccinia graminis avenae* E. and H. Plates 3 to 5 illustrate the typical effect of *P. glumarum tritici* upon resistant hosts. Large areas of killed tissue develop on the portions of the leaves inoculated, followed by the production of very few if any uredinia. Upon varieties which are moderately resistant, urediniospores often are produced in abundance but no spread of the rust occurs from the parts of the leaf inoculated, and these portions are soon killed.

Parker (*15*) interprets purple blotches adjacent to the uredinia as evidence of resistance of oats to *P. graminis avenae*. As indicated in Table II and as illustrated in Plate 3, A, dark brown spots often develop on certain grass hosts when inoculated with urediniospores of *P. glumarum tritici*. Similar brown discoloration often appears around the edge of the uredinia on fairly susceptible grasses such as *Bromus sterilis*, *Bromus sitchensis*, and others. This type of reaction has been noted only on certain species of grasses. Parker (*15*) also found that the production of telia of crown rust on seedlings of oats in the greenhouse was an indication of resistance. Although in a few cases telia have developed in the greenhouse upon wheat seedlings in connection with the work herein reported, this has been interpreted as being due to the effect of certain environmental conditions upon the host rather than as a sign of resistance.

SUMMARY

Field collections of *Puccinia glumarum* in the western part of the United States have been made on wheat, barley, rye, spelt, and emmer, as well as on 33 wild grasses.

It has been shown by artificial inoculation that the rust also will infect 26 additional grass hosts. This makes a total of 59 species of wild grasses which are hosts for this rust as it occurs in the United States.

The common specialized variety of stripe rust in the United States is the one peculiar to wheat, *P. glumarum tritici* Erikss. and Henn. Field observations indicate that the variety developing on barley, *P. glumarum hordei* E. & H., also occurs in this country.

The specialized variety from wheat also will infect rye moderately and barley slightly. Inoculation experiments have shown that this variety also will infect 47 wild grasses. This list includes 19 species of Bromus; 11 species of Agropyron; 7 species of Hordeum; 7 species of Elymus, and one species each of Hystrix, Phalaris, and Sitanion. Stripe rust has been collected in the field on twelve additional grass hosts, but it has not yet been possible to ascertain if these also are hosts for the specialized variety from wheat.

There has been some evidence that there are several strains of the different grass species which react differently to the same variety of the rust. There has been some indication also that there are two or more strains or specialized forms of *P. glumarum tritici*.

Varieties of wheat and wheat allies to the number of 163 have been tested for resistance to stripe rust in a rust nursery at Corvallis, Oreg., where an epiphytotic of this rust was produced artificially each year for three years. All of these varieties were grown for two years and part of them for three years. The results of these experiments are presented in tabular form.

Ninety-two varieties of wheat have been tested for resistance to stripe rust in the greenhouse. Some of these were studied three years, some of them in two years, and some of them in only one year. The results of these experiments are given in tabular form. With few exceptions the results of the field and greenhouse studies have agreed quite closely.

There is a very marked difference in the susceptibility of various wheat varieties to stripe rust. More of the common wheat varieties appear to be resistant to stripe rust than are resistant to stem rust. When more strains of stripe rust are tried this may not continue to be the case. Comparatively few of these varieties which were studied became infected

in the head under the conditions of the experiment. Varieties which developed head infection were greatly reduced in yield.

Leaf infection in the seedling stage has been more severe in spring-sown wheat. Leaf infection at heading time has been more severe in fall-sown wheat.

Several varieties have proved very resistant to the strains of the rust studied. Resistance is evidenced by the development of large areas of killed tissue in the portions of the leaves inoculated, followed by the production of few or no uredinia.

Dark brown blotches and browning around the edges of inoculated areas have developed upon certain grass hosts. This characteristic appears to be specific for certain grasses and has not been considered a general sign of resistance.

Telia have been formed in the greenhouse in a few cases under certain conditions. This was thought to be due to the conditions surrounding the host and was not regarded as a sign of resistance.

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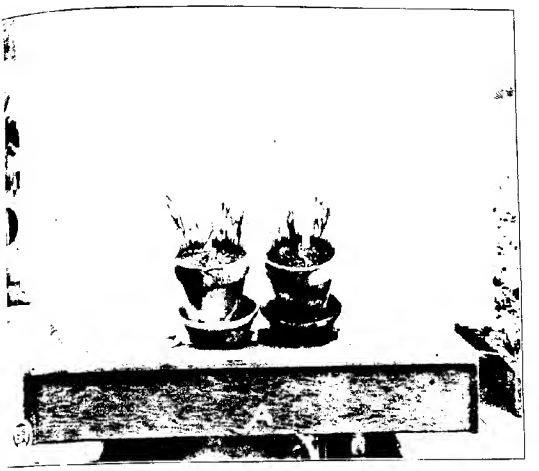
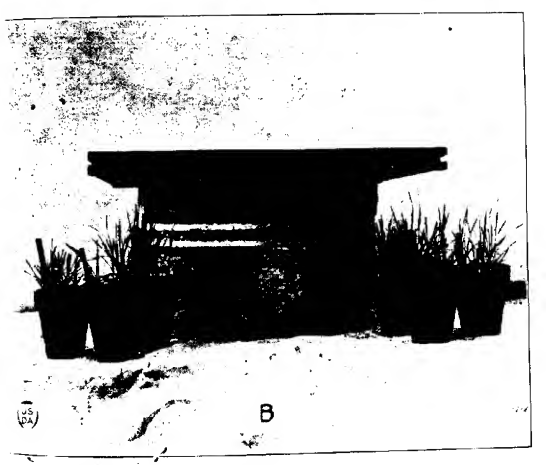
PLATE 1

Method of growing the wheat seedlings for study of specialized races.

A.—Bell jar and battery jar used as incubation chambers, and pots containing wheat seedlings, showing method of separating the plants in each pot into two groups, one group being inoculated and the other used as control.

B.—Tub covered with window sash, used as an incubation chamber. Half the plants in the pots were inoculated, the pot placed in the tub in about 2 inches of water and the tub covered with the sash for 48 hours.

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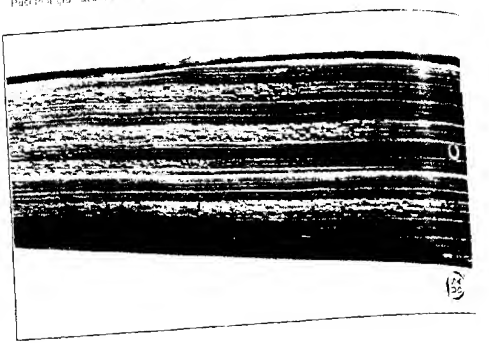
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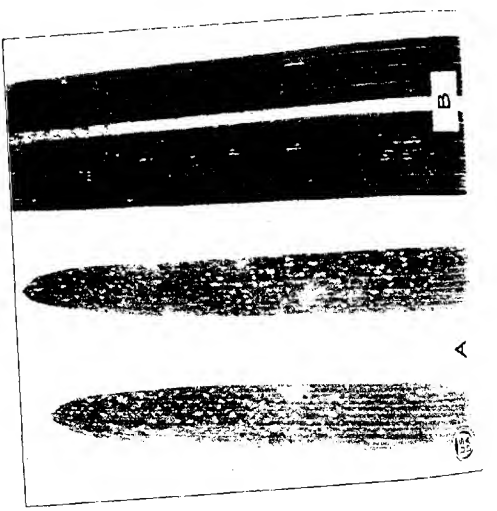
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PLATE 2

Normal development of uredinia of *Puccinia glumarum tritici* on wheat leaves.

A.—Distal portion of a leaf of a seedling of Chul, showing abundant infection and production of uredinia.

B.—Portion of an older leaf of Chul, showing very abundant infection in the form of a single, longitudinal stripe.

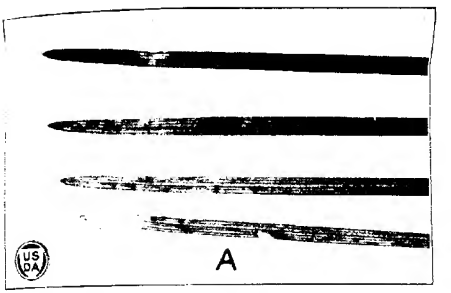
C.—Portion of a leaf of Little Club wheat, showing abundant infection and production of uredinia.

PLATE 3

Portions of inoculated leaves showing flecks or areas of tissue injured or destroyed by the fungus but no permanent infection resulting. This condition represents grade o in the five gradations of susceptibility to infection by *Puccinia glumarum tritici*.

A.—Portions of mature leaves of *Bromus carinatus* showing distinct brown blotches.

B.—Portions of mature leaves of Red Russian wheat showing large spots of killed tissue.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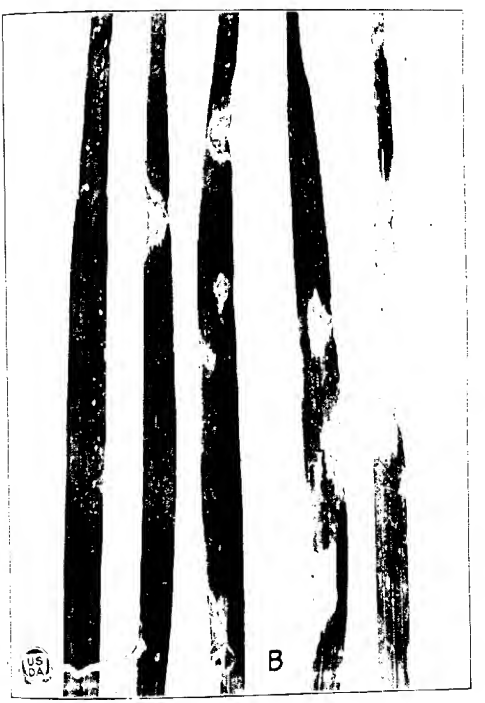
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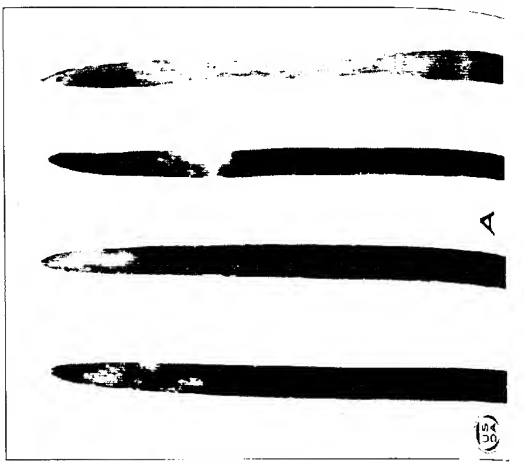
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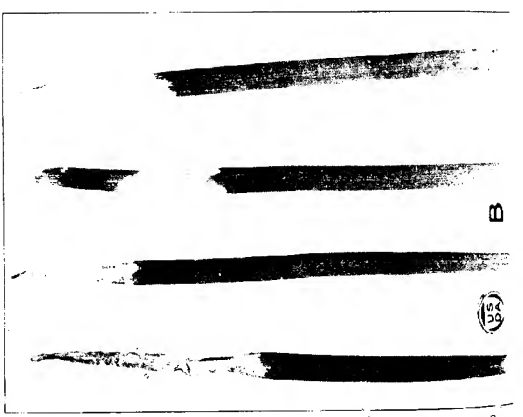
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PLATE 4

Portions of inoculated leaves showing flecks or areas of tissue injured or destroyed by the fungus but no permanent infection resulting. This condition represents grade 2 in the five gradations of susceptibility to infection by *Puccinia glumarum tritici*.

A.—Distal portion of leaves of Barletta wheat (C. I. No. 3297).

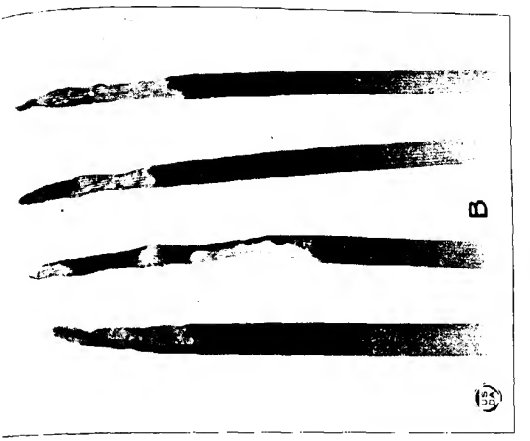
B.—Distal portion of leaves of Einkorn (C. I. No. 2433).

PLATE 5

Portions of inoculated leaves showing uredinia few or minute, usually surrounded by areas of dead or discolored tissue. This condition represents grade 1 in the five gradations of susceptibility to infection by stripe rust.

A.—Distal portions of leaves of Sonora wheat (C. I. No. 3036).

B.—Distal portions of leaves of Einkorn (C. I. No. 2973) 18 days after inoculation.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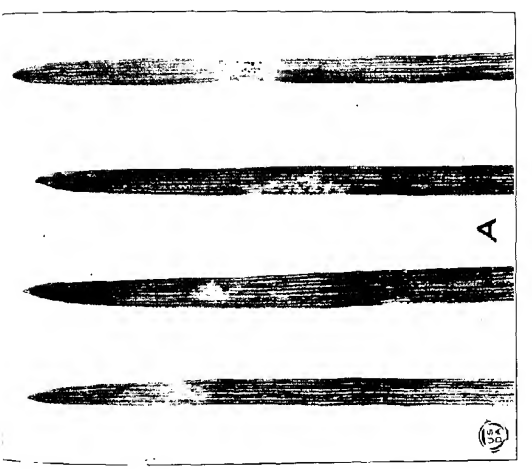
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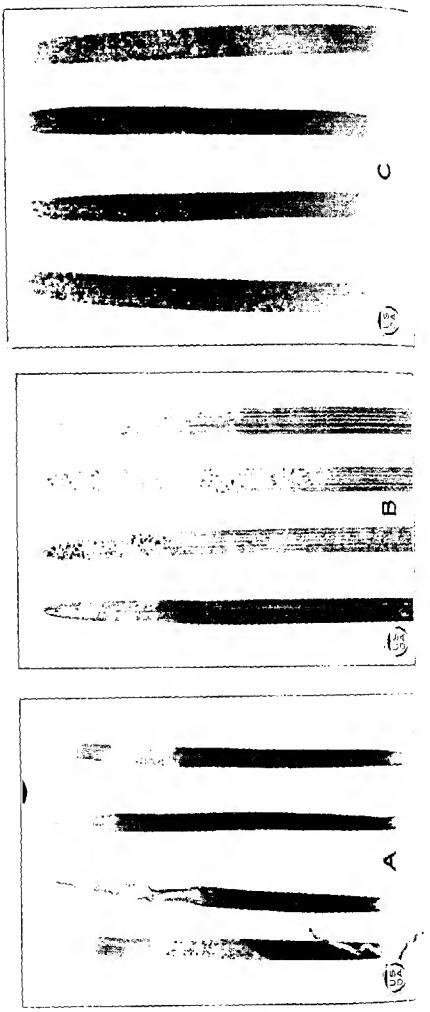
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B
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PLATE 6

Portions of inoculated leaves showing effects of inoculation with *Puccinia glumarum* (Schm.).

A.—Distal portions of leaves of Red Winter spelt (C. I. No. 1772), showing normal uredinia, but few and scattered, with leaf tissue abundantly discolored. This condition represents grade 2 of the five gradations in susceptibility to infection by stripe rust.

B.—Distal portions of leaves of *Bromus sterilis*, showing uredinia normal and moderately abundant, with but little discoloration of leaf tissue. This condition represents grade 3 of the five gradations in susceptibility to infection by stripe rust.

C.—Distal portion of leaves of Black Winter emmer, showing uredinia normal and abundant, scattered uniformly over surface of leaf, with no discoloration in the early stages of infection. This condition represents a grade of 4, or very susceptible, in the five gradations in susceptibility to infection by stripe rust.

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ORIGIN AND CONTROL OF APPLE-BLOTCH CANKERS[1]

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INTRODUCTION

On account of the great significance of the twig cankers as a means of overwintering and source of early infection of the apple-blotch fungus (*Phyllosticta solitaria* E. and E.), knowledge of the mode of origin of these cankers is highly important. Likewise any new light on methods of canker prevention and eradication is much to be desired.

The identity and significance of the blotch cankers were discovered about the same time by Scott and Rorer (*14*)[3] and by Sheldon (*16*), and petiole lesions were described by Sheldon and later by Scott and Rorer (*15*), who made an incidental observation of peculiar interest. They found a large percentage of the fruit buds in an orchard of Limbertwig, Missouri, and Ben Davis trees in Arkansas being killed in midsummer and attributed this in part to the apple-blotch fungus (*15, p. 11*) which according to their observations and cultural work "extended down from diseased leaf petioles into the twigs at the base of the buds, which were soon killed." Apparently, no significance was attached to this phenomenon in connection with the origin of cankers, since they mention spore infection of the twigs.

Lewis (*10, p. 528, 533*), who studied this disease on the Missouri variety in Kansas, states in connection with fruit spur cankers that "the fungus sometimes enters from the leaf stem, and at other times through the new growth just below the bud," and in connection with the importance of leaf infection he mentions the "possible infection of the twig from the petiole."

Roberts (*12, 13*) was able to produce cankers on young twigs and watersprouts by spraying with a water suspension of the spores, but was unable to infect older branches in this way and also was unable to cause infection of twigs by wound inoculation. These results would indicate that cankers are the result of germ tube infection through the uninjured epidermis of very young wood.

A study of the blotch cankers on the Northwestern variety at Mooresville (orchard of Mr. D. B. Johnson) and Knightstown (orchard of Mr. J. B. Hamer), in central Indiana, from 1919 to 1922, and on the Oldenburg variety at Mitchell, in southern Indiana, in 1921 and 1922, indicates that a large percentage of the cankers on twigs are the result of invasion from infected petioles rather than of direct spore infection (*7*). The

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[2] The writer wishes to acknowledge his indebtedness to Prof. H. S. Jackson for helpful suggestions and to Prof. Laureus Greene, Mr. C. E. Baker, and Mr. R. A. Simpson for their cooperation.

[3] Reference is made by number (italic) to "Literature cited," p. 417-418.

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